INFLUENCE OF THE COOLDOWN AT THE TRANSITION TEMPERATURE ON THE SRF CAVITY QUALITY FACTOR

Oliver Kugeler, Julia Vogt, Jens Knobloch

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HZB Helmholtz Zentrum Berlin

Introduction

- Many new accelerator applications require CW SRF. Focus shifts to dynamic losses.
- Cryogenics = cost driver
- Minimize cryogenic load $P_{diss} \sim R_{surf} E_{acc}^{2}$
  - Want low surface resistance at moderate gradients
- $R_{surface} = R_{BCS}(f, T) + R_{residual}(?)$
- We found that cavity cooldown procedures have an impact on R_{res}
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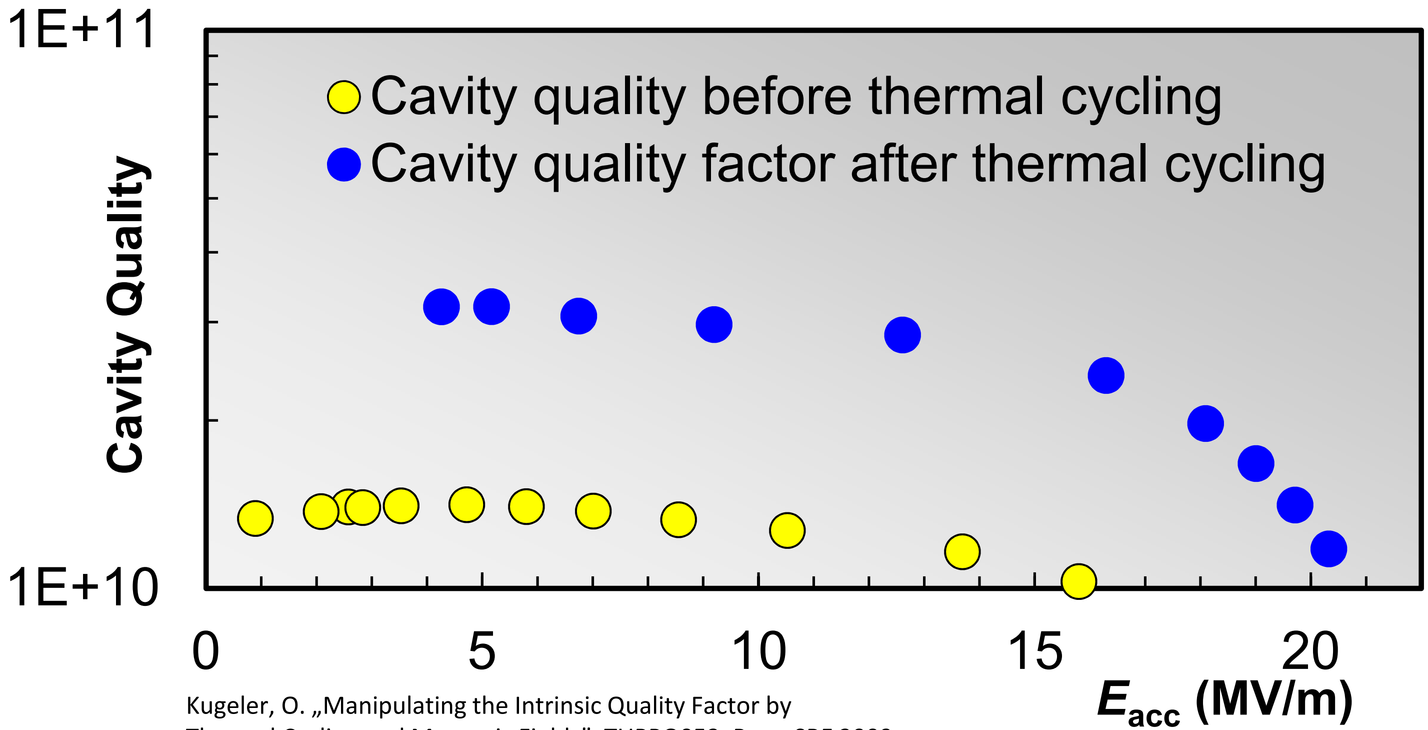
Flashback to SRF 2009



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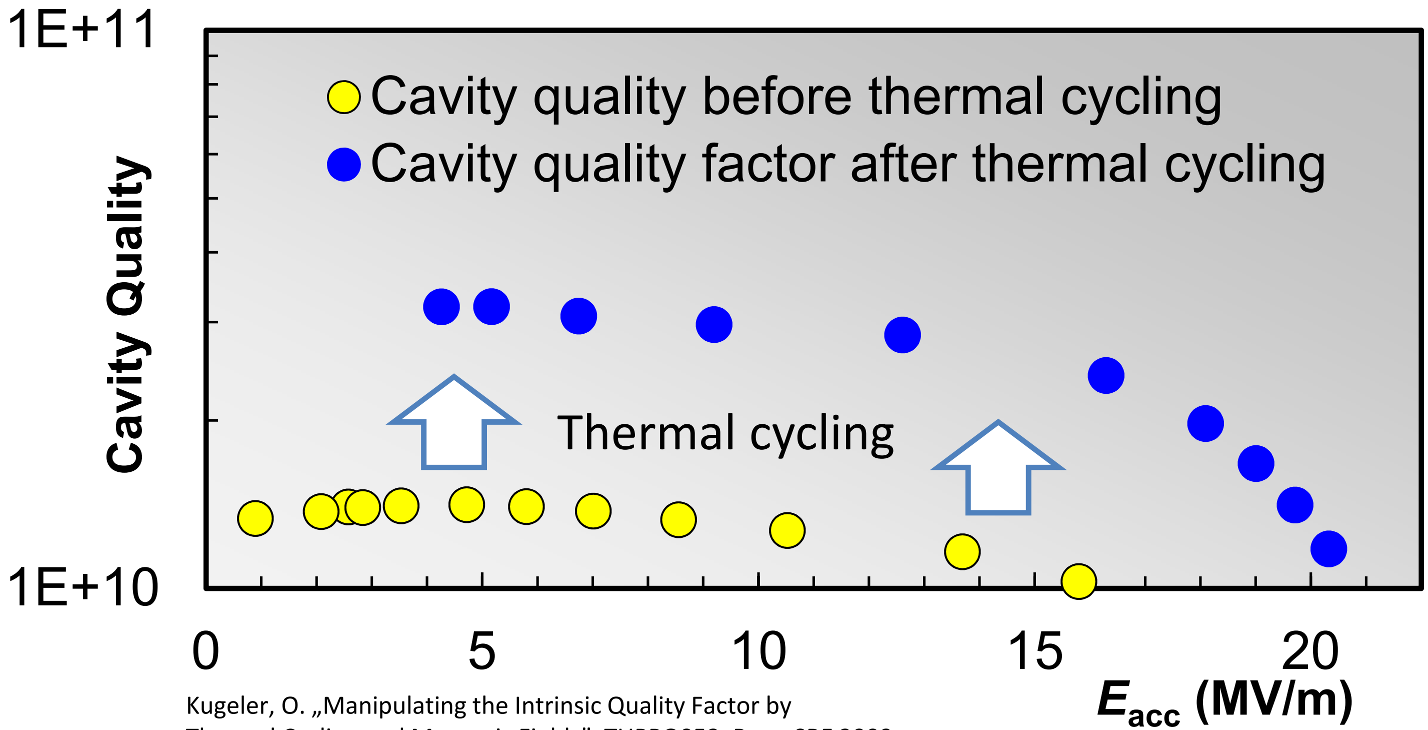

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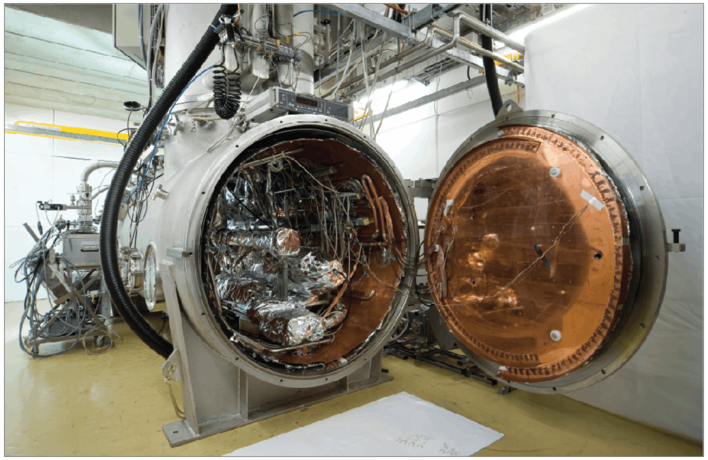
- Measured Q increase upon "thermal cycling" to about 40 K
- Effect not understood back then. New investigations have yielded an explanation: thermocurrents

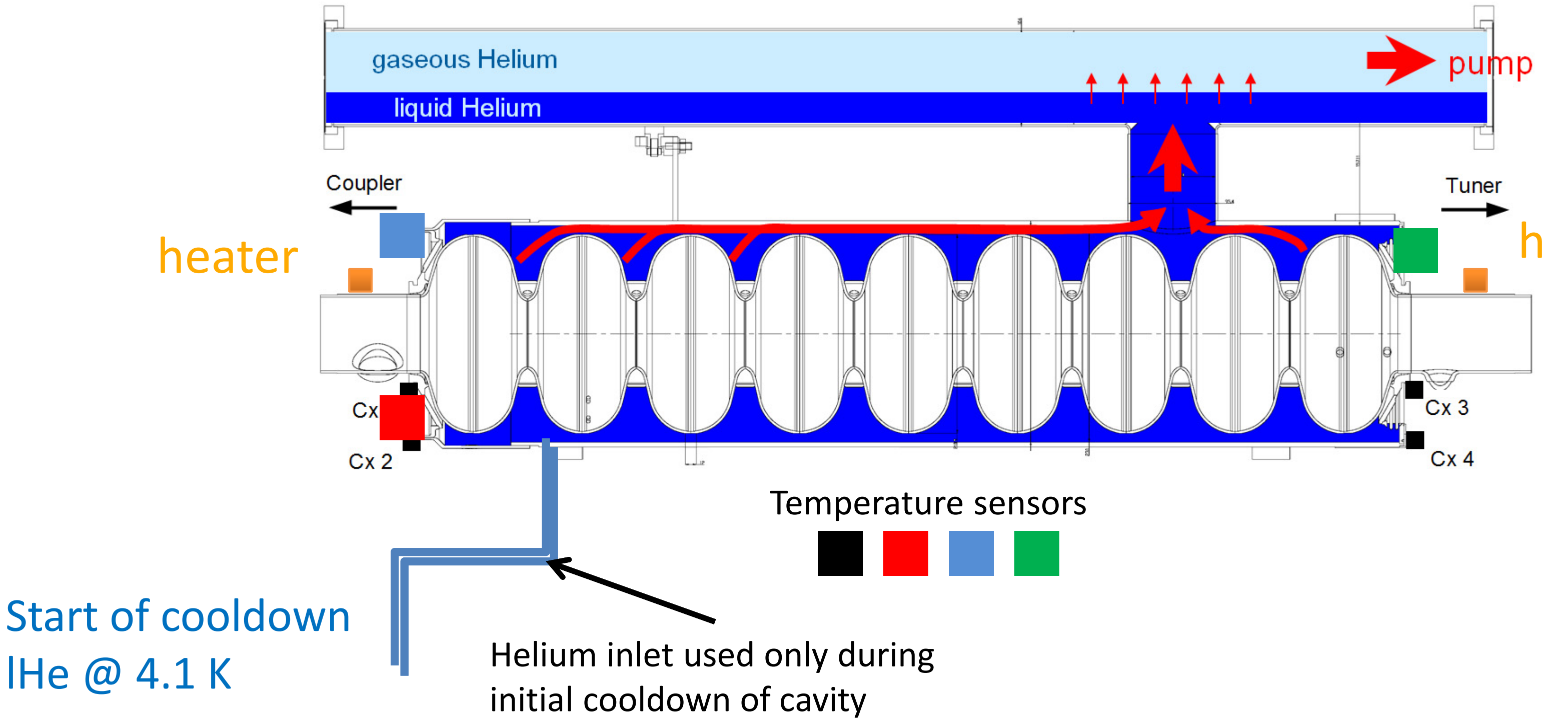
Q_0 vs T measurements

- HoBiCaT test facility used
- Horizontal, fully equipped industrial cavity welded into Helium tank
- Configuration like in accelerator module
- Temperatures down to 1.5 K
- All measurement done with one cavity in one measurement run!



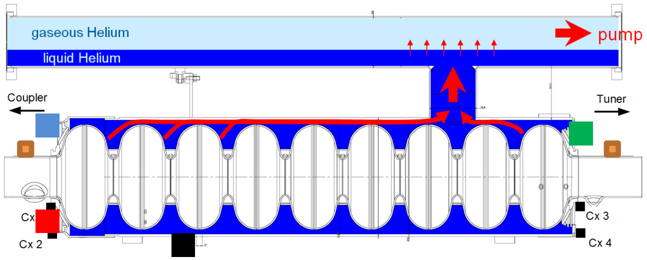
- Double magnetic shielding (warm shield + cryoperm)
  Small residual fields < 1 µT
- TTF-III coupler, near critical coupling (0.8 < β < 2.5)
- Verification of RF measurements with LHe-loss measurements and Lorentz detuning
  Error assumed smaller than 10%

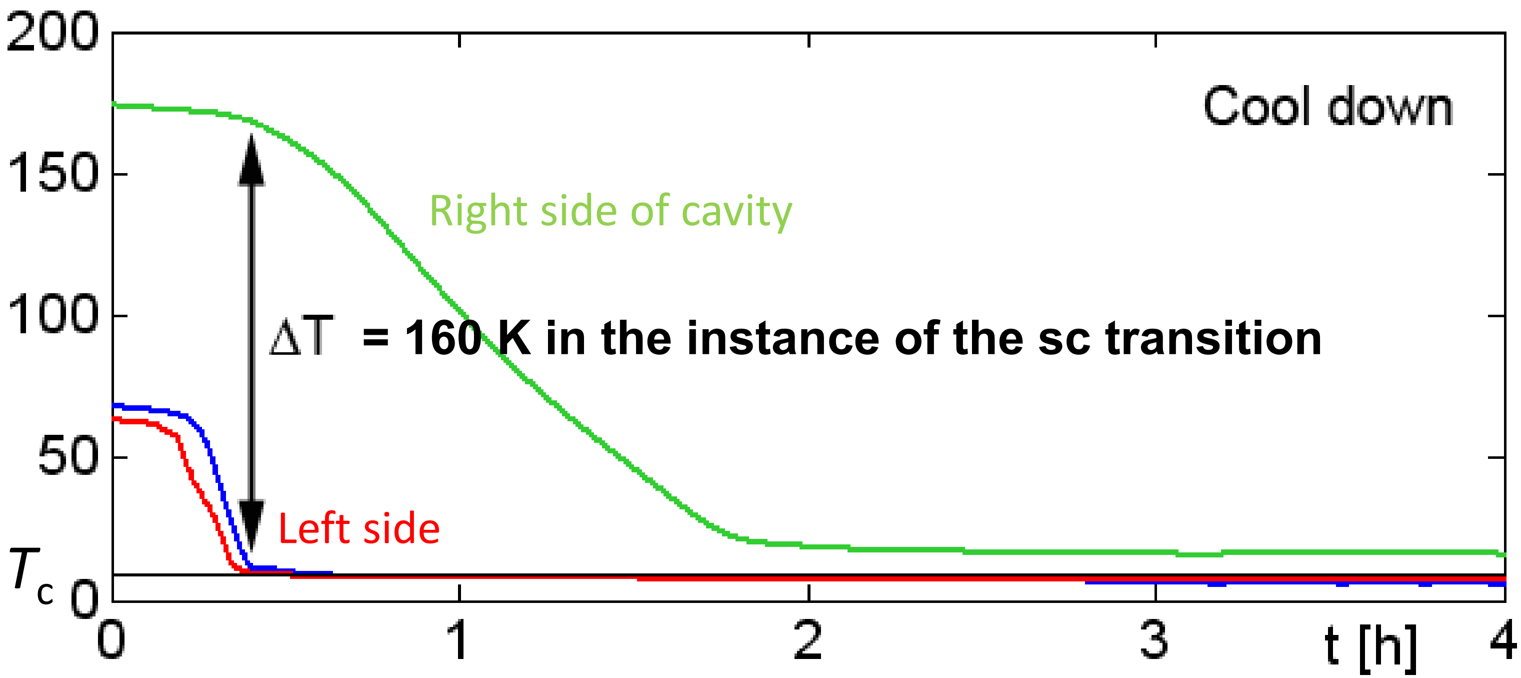
Cavity cooldown procedure



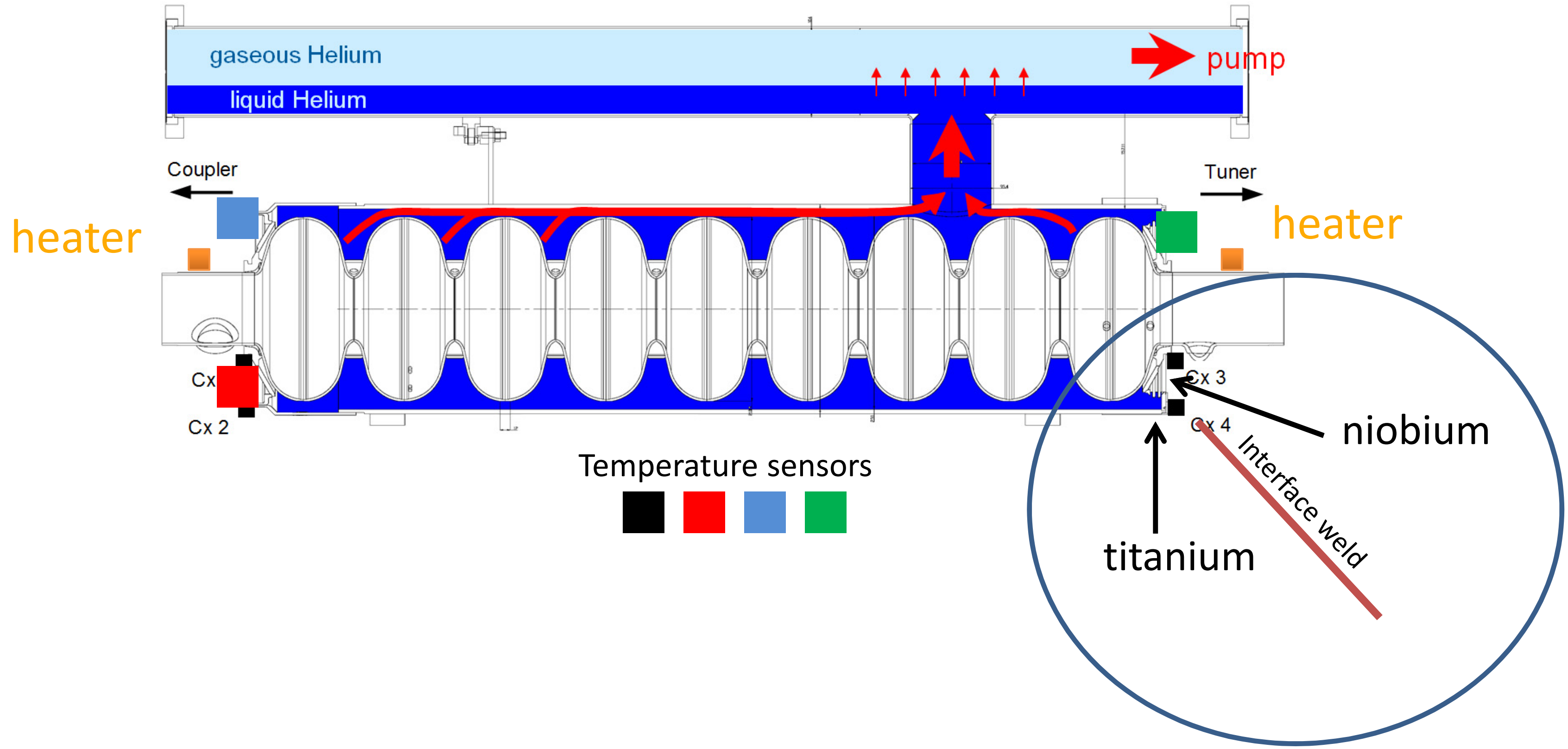
Dynamics of Helium filling leads to large temperature gradients

Initial cool down



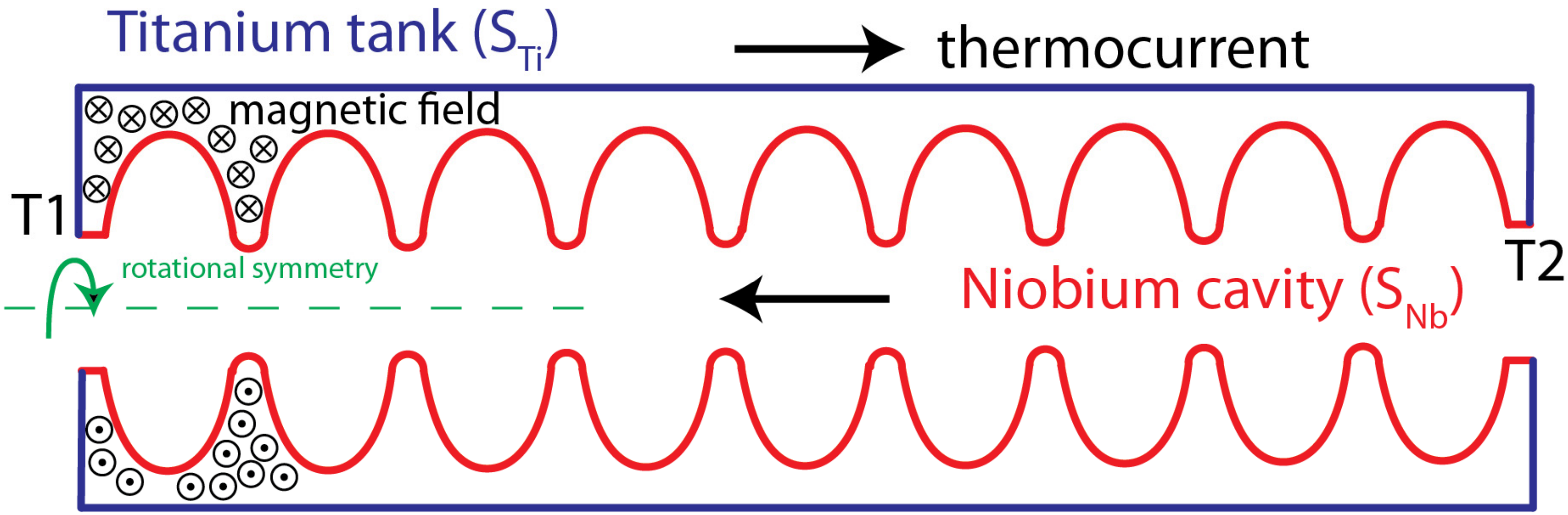


Materials interfaces in cavity with tank



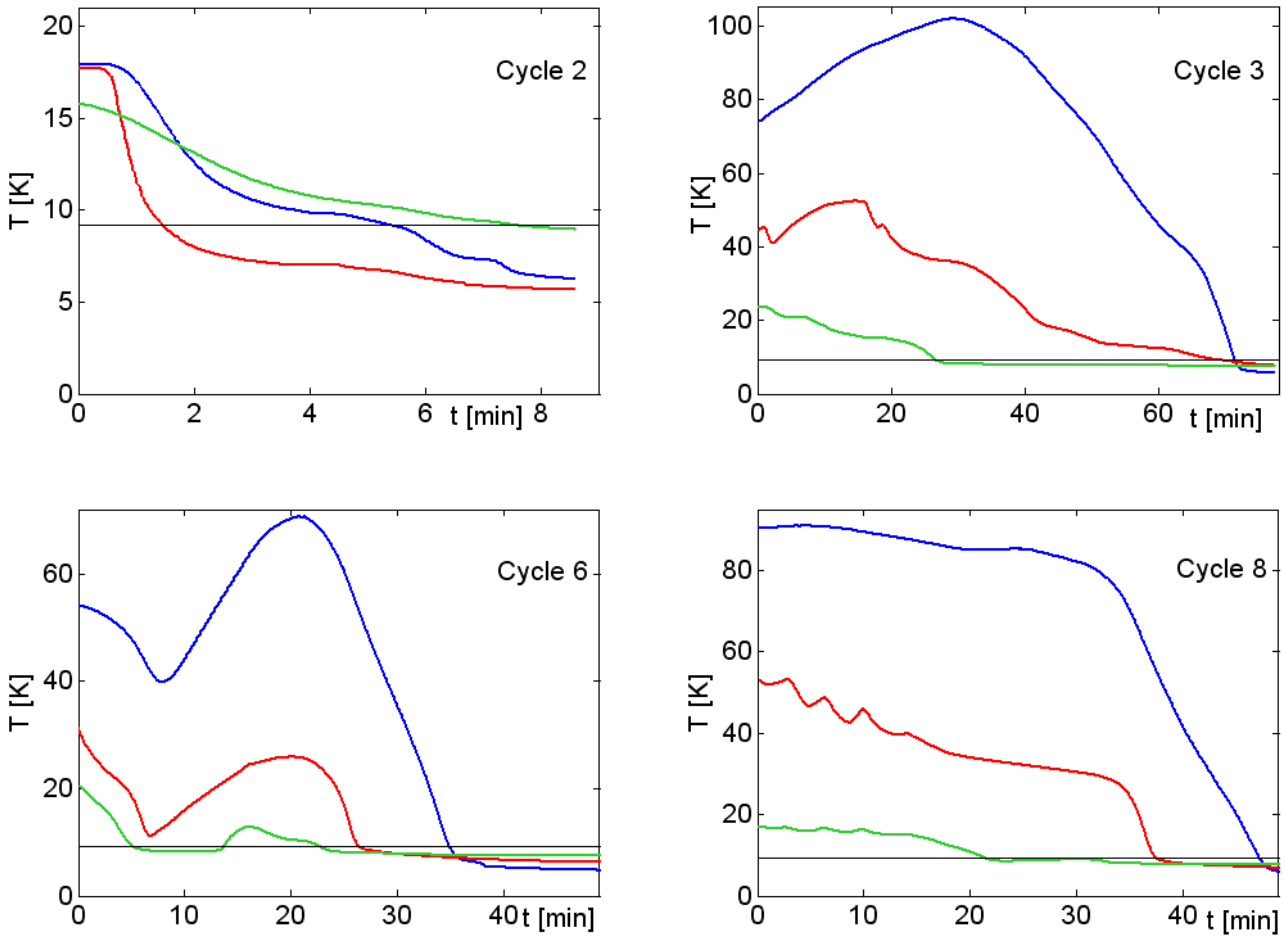
Thermocurrents

- Cavity forms thermoelement
- Different Seebeck coefficients for Nb and Ti



$$U_{thermo} = (S_{Niobium} - S_{Titanium}) \cdot \Delta T$$

Cycling temperature profiles



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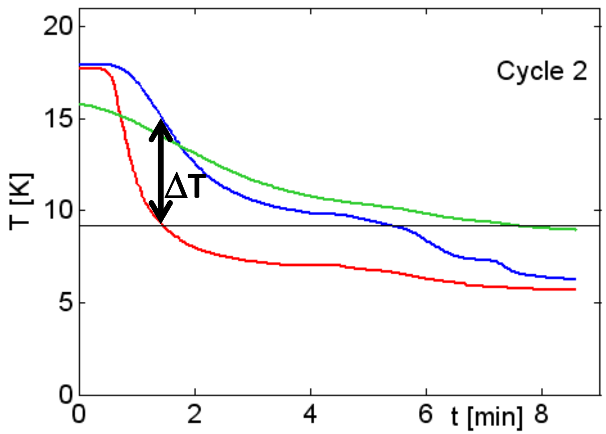
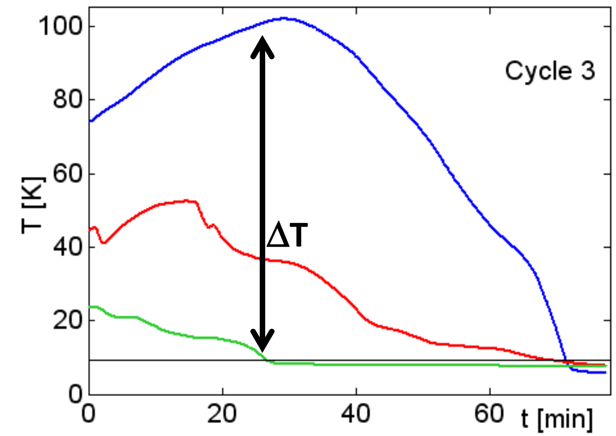
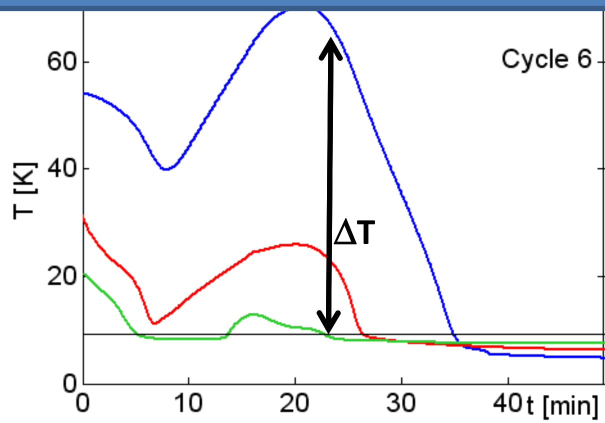
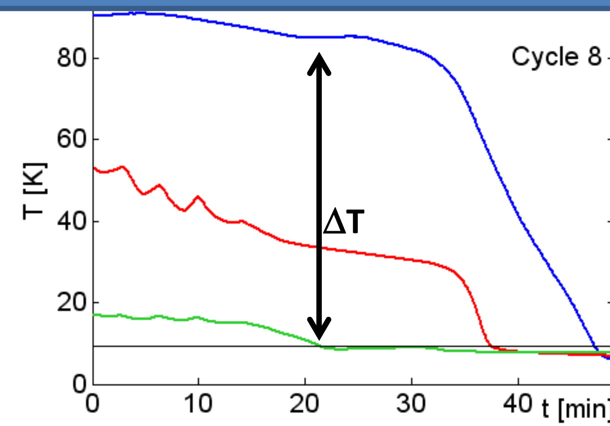




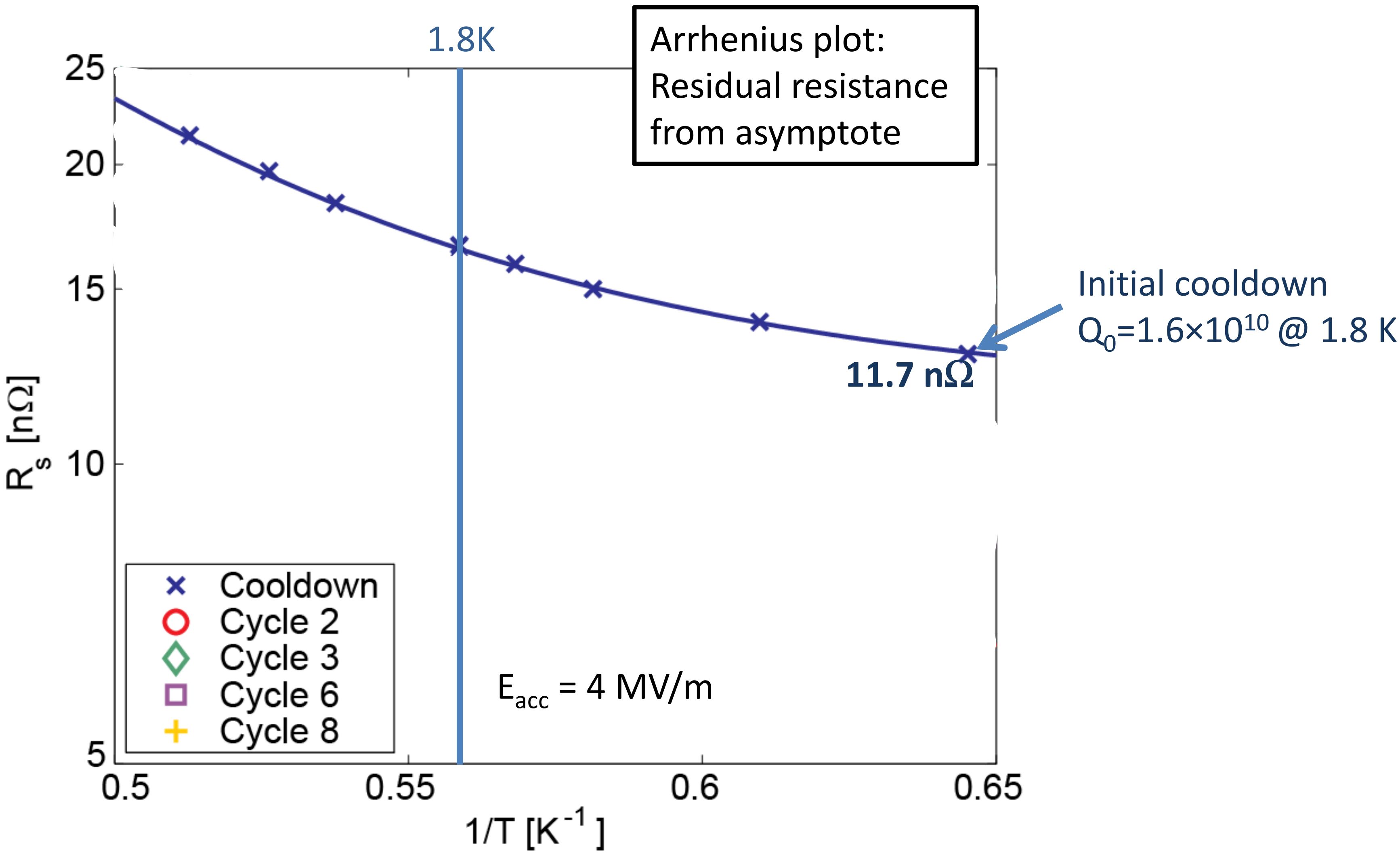
Temperature difference between cavity ends when one end is making transition





Generated temperature differences between 5 K and 90 K

Surface resistance measurements



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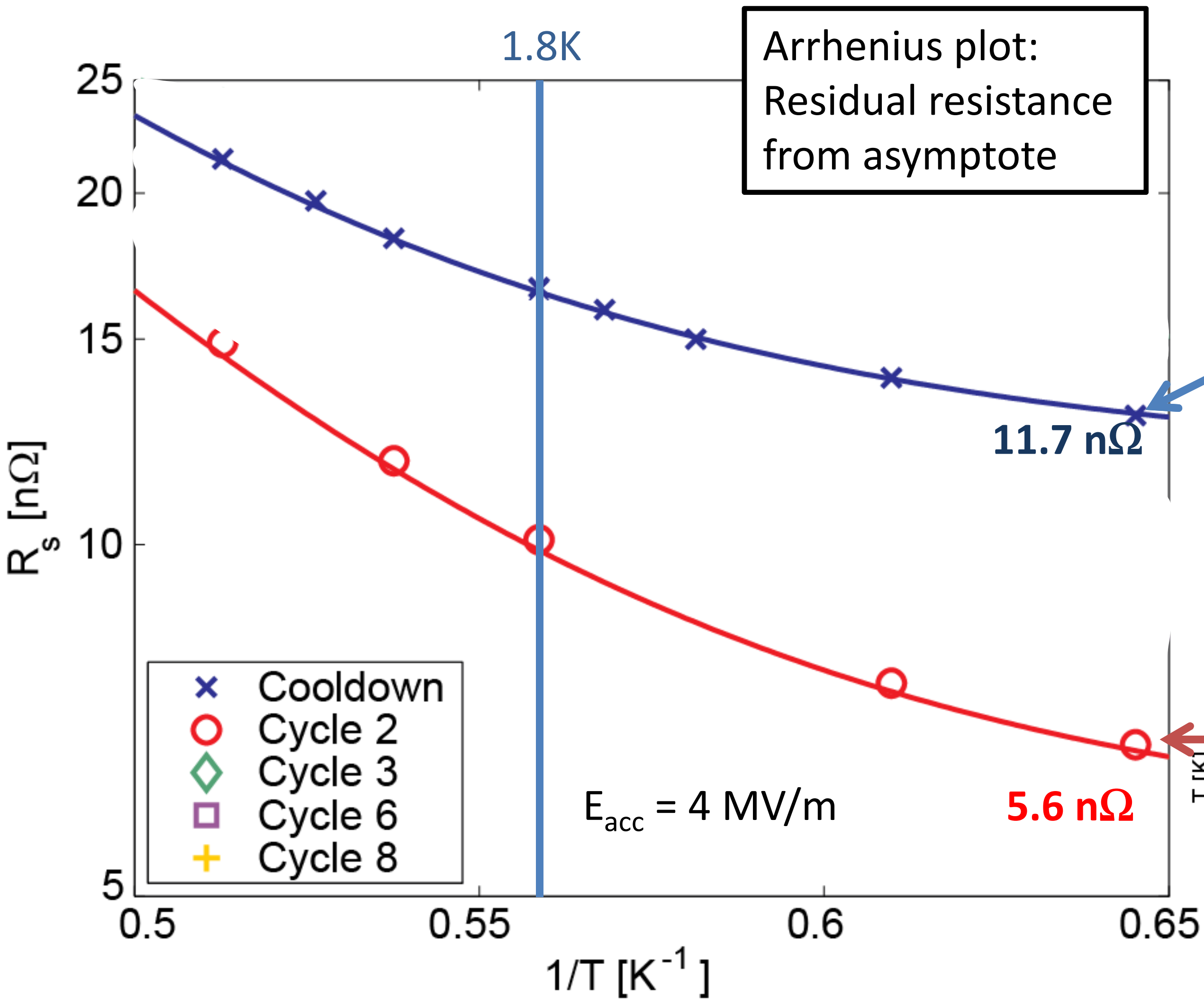
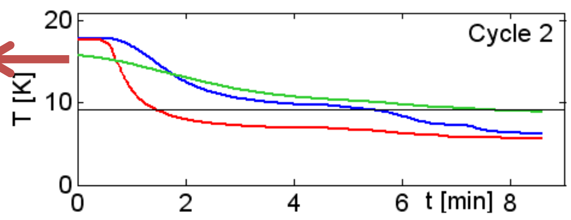


Initial cooldown
Q_0=1.6×10^{10} @ 1.8 K



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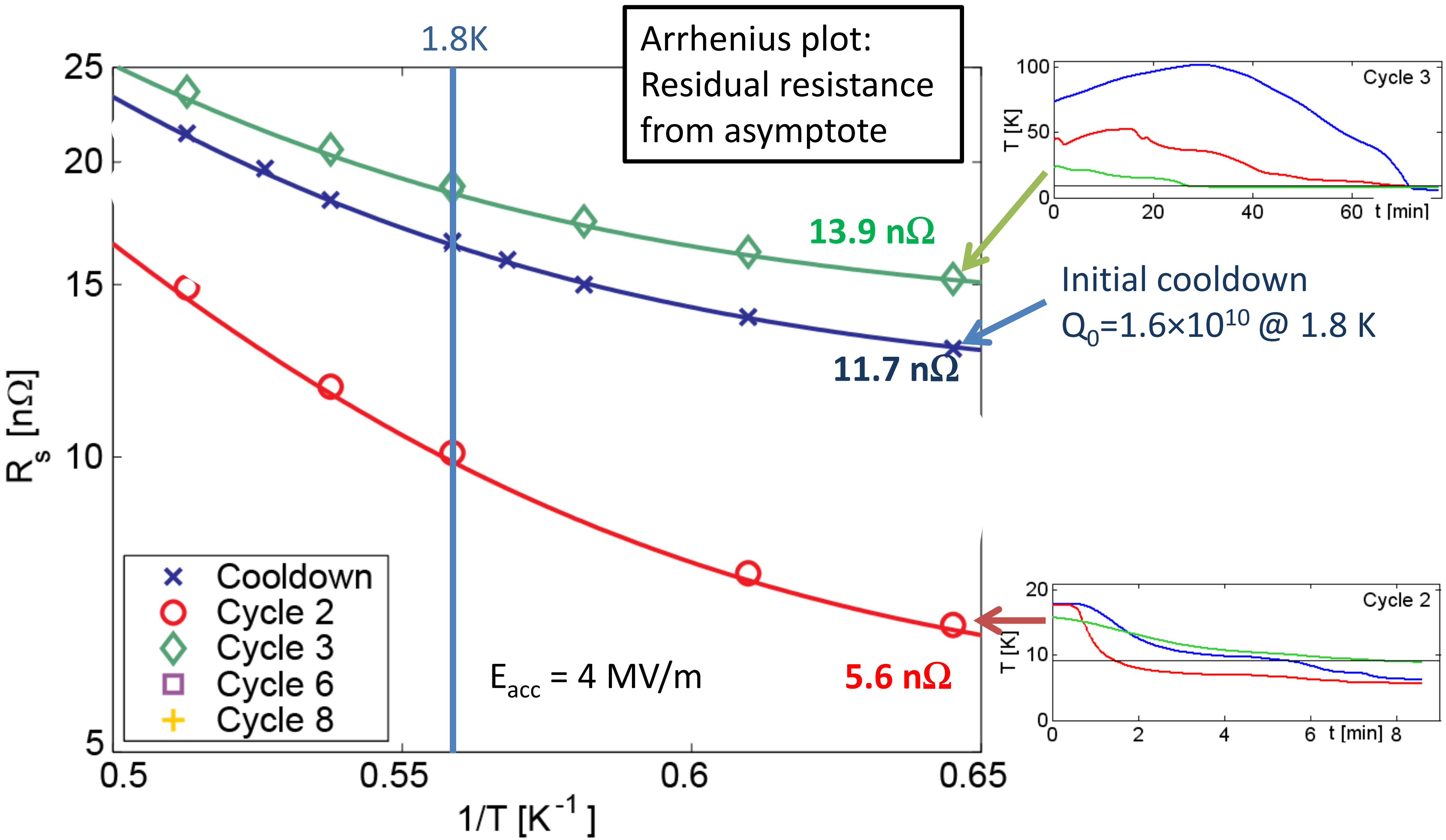

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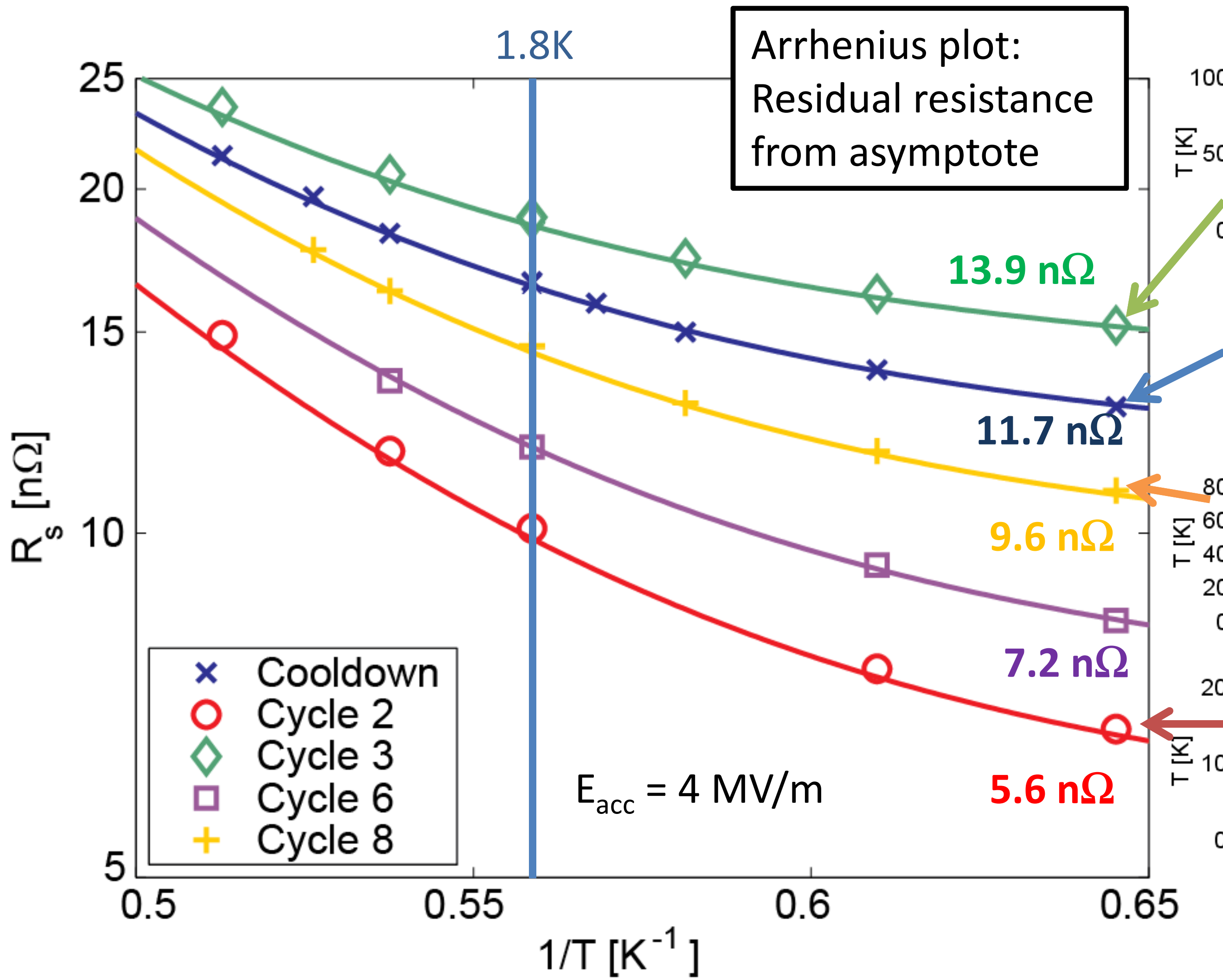

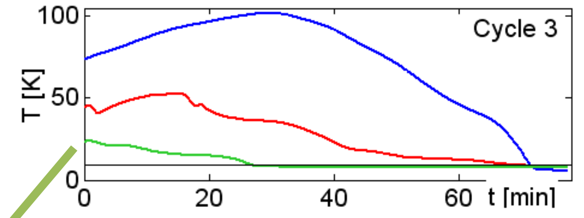

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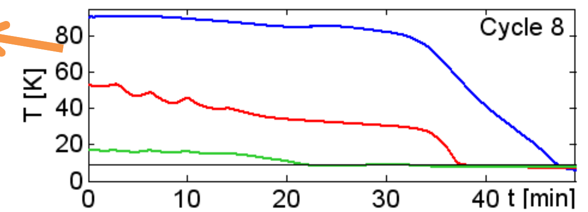
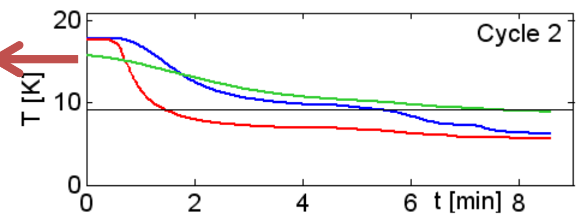
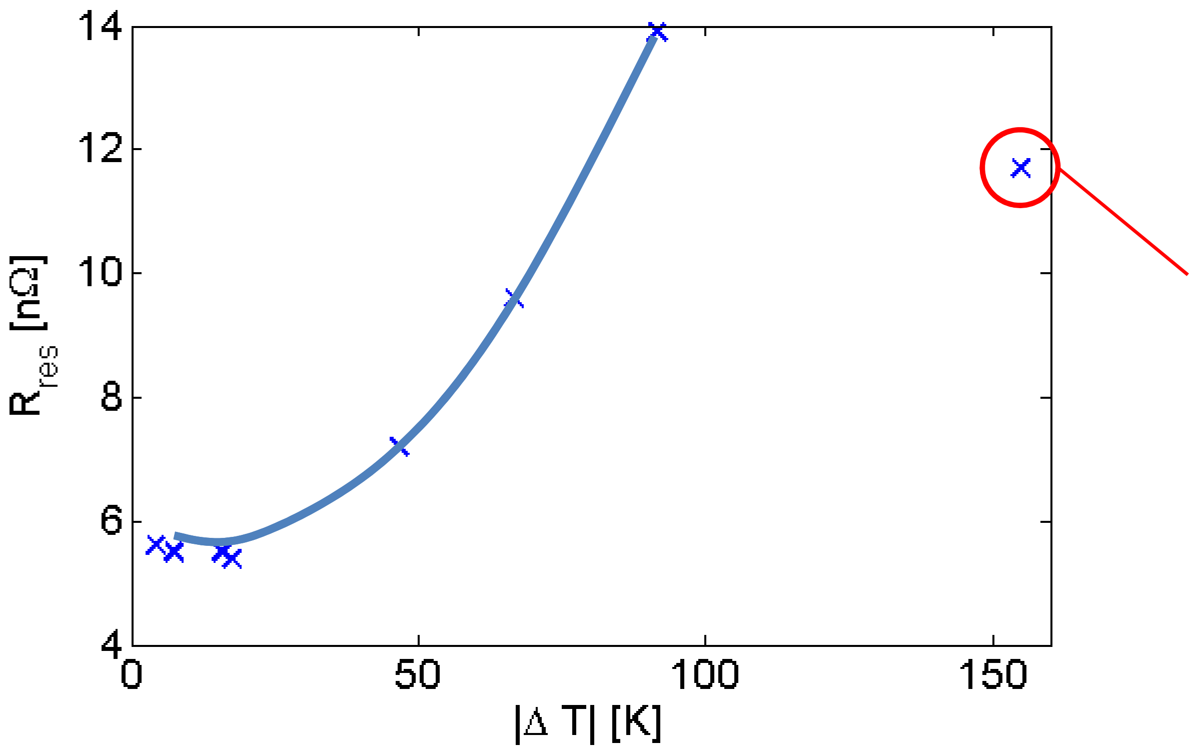




Results



Clear increase of R_{res} with ΔT

Initial cool down (very different temperature profile due to LHe filling from bottom)
→ difficult to "compare apples with oranges"

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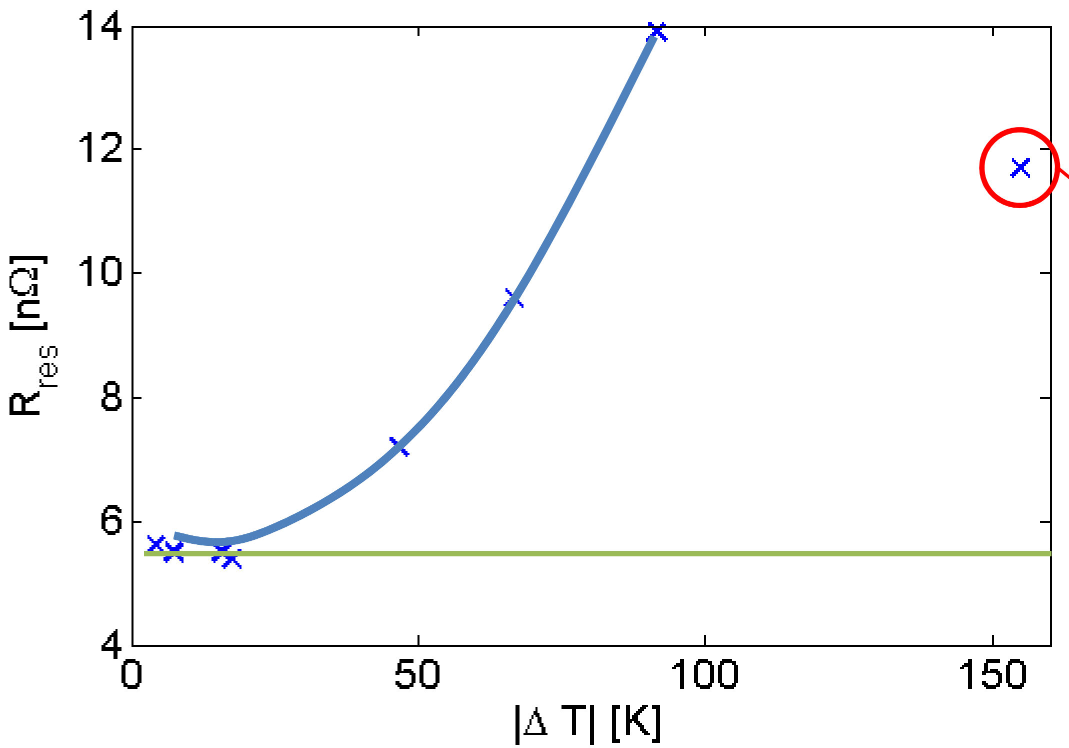

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Lowest limit achieved
Residual resistance due to other mechanisms or ambient magnetic field

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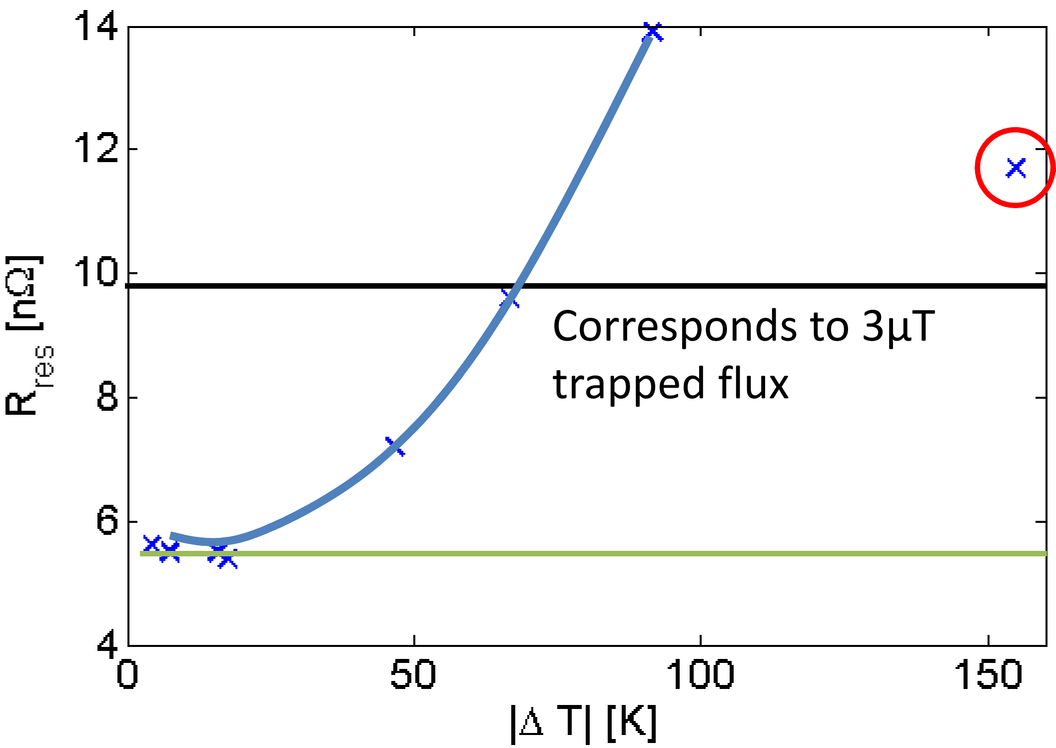

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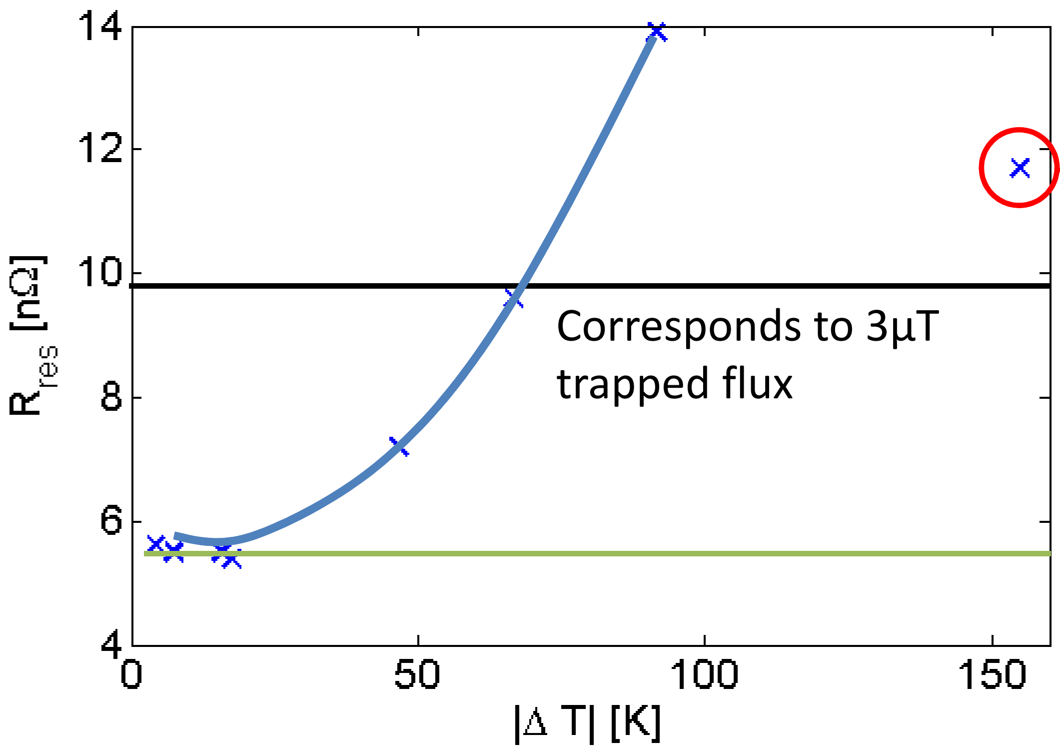

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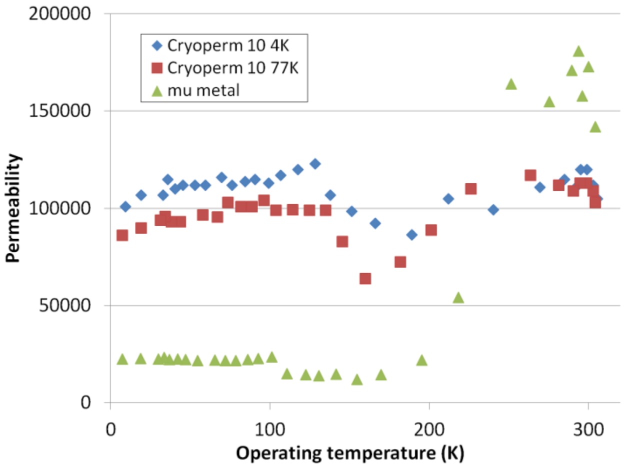
$$U_{thermo} = (S_{Niobium} - S_{Titanium}) \cdot \Delta T$$

U_{thermo} drives thermocurrent and thus generates extra ambient field

Discarded reasons for R_{res} variation

Hypothetical reasons for the improvement of R_{res}	**Not the reason here because**
surface morphology	same cavity
RRR	
crystallinity, granularity	
total hydrogen content	
systematic differences	measurement taken in same run
calibration errors	
magnetic shielding efficacy	shield μ_r constant
adsorbate removal	process irreversible
Q-disease	never leads to decrease of R_{res}



Chronological order of measurements

Procedure	R_{res} (nΩ)	ΔR_{res}	ΔT
Cooldown	11.7		150
		decrease	
Cycle 1	*6*		*~5.5*
		decrease	
Cycle 2	5.6		~5.5
		increase	
Cycle 3	13.9		90
		decrease	
Cycle 4	*5.4*		*~5.5*
		increase	
Cycle 5	*5.5*		*~5.5*
		increase	
Cycle 6	7.2		45
		decrease	
Cycle 7	*5.5*		*~5.5*
		increase	
Cycle 8	9.6		67

Change in R_{res} reversible

Conclusion and outlook

- Improve residual resistance by thermal cycling
- Factor of 2 improvement and reduction is demonstrated depending on cycling conditions.
- Thermocurrents most plausible explanation as a source of additional magn. flux that is trapped during the SC transition.
- Implement additional step in standard cavity cooldown procedure.
  - Pause cooldown a little above T_c long enough to reach thermal equilibrium (presumably > 12 hours)
  - Alternatively, introduce additional short thermal cycle above T_c.
- Implemented in HoBiCaT procedure, but cryoplant currently down so that tests have not yet been possible.